

Diesel Impacts at Ski Areas and the Biodiesel Alternative

Green Slopes Series 2007

Reducing Emissions One Engine at a Time

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Today's Presentation---Answers to:

- **What are the benefits and challenges for Diesel Engines??**
- **What led to 2007/2014 Standards for Diesel Engines and Fuels?**
- **What does Keene State College have to do with any of this?**
- **What does Biodiesel have to do with any of this?**
- **Why is this relevant to ski areas?**

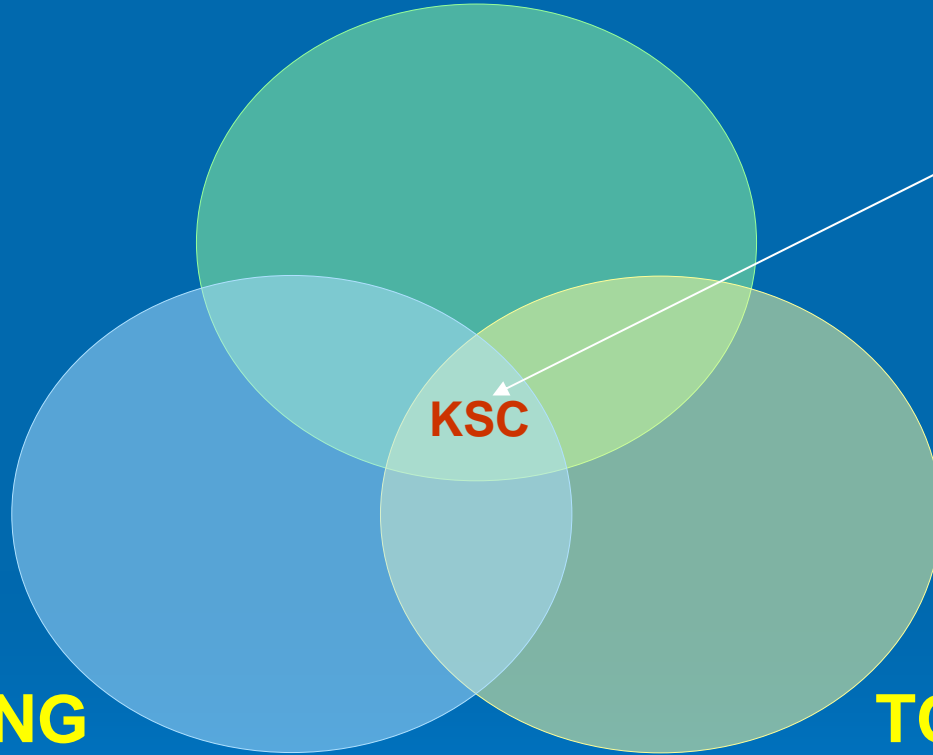
**DECISION-MAKING
& POLICY**

Non-Road
Diesel
Engine
Emissions

KSC

ENGINEERING

TOXICOLOGY



Diesel Fuel (Benefits)

Many desirable qualities:

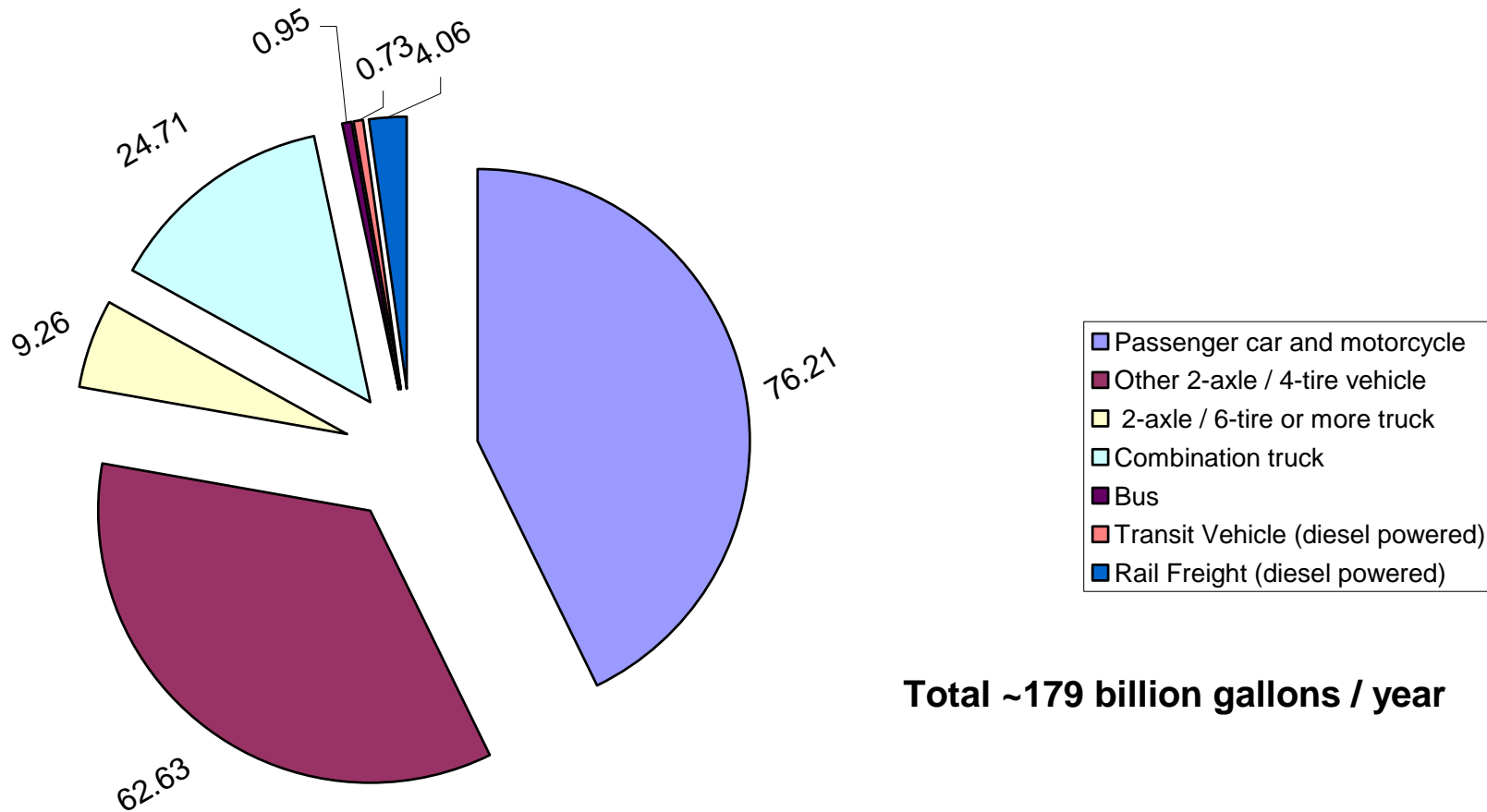
Efficient fuel,

Effective fuel/technology,

Available fuel,

Current system established....economic
impact

**Annual Petroleum (Diesel and Gasoline) Use in United States
2004 Usage in Billions of Gallons**



Diesel Fuel (Challenges)

- Increasing concerns regarding health and environmental impacts of diesel equipment
- Increasing awareness of the emissions contribution to pollutants of concern from diesel engines

Critical Events/Study

- 1999: California study---MATES I and II—and regulation
- 2000: USEPA finalizes Diesel Health Assessment Document
- 2000 – current day: Non-road equipment exposure analyses at Keene State College, raising concern regarding potential impacts
- 2000-2006: USEPA tightens engine and fuel standards for on-highway and non-road diesel engines and tightens the national ambient air quality standard for fine particulate matter

The Major Health Concerns with Diesel:

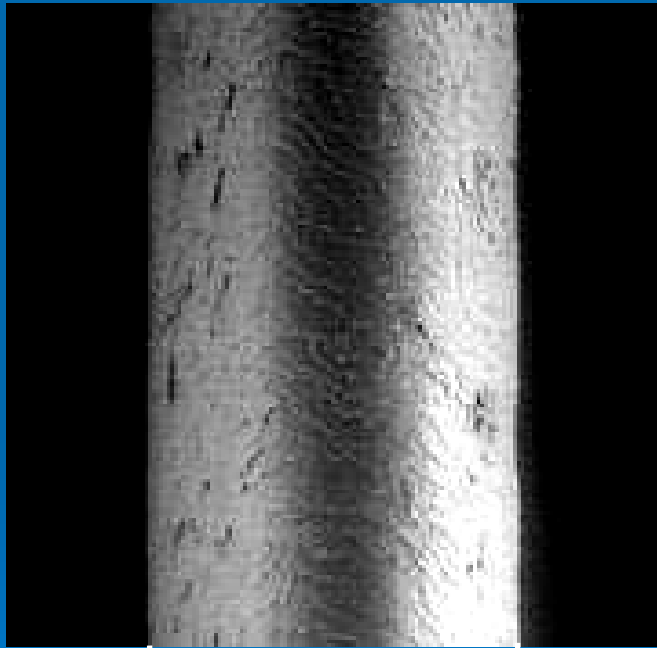
- *Fine and Ultrafine Particulate Matter*
- *Volatile and semi-volatile organic compounds*
- *Cancer causing mixture?*

Major Environmental Concerns:

- *NO_x*
- *Volatile organic compounds*

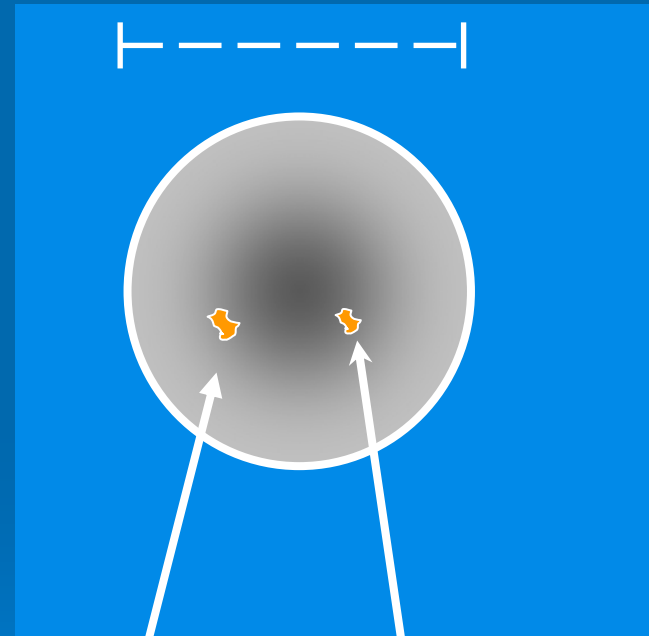
What are Fine and Ultrafine Particles?

A complex mixture of extremely small solid particles and drops of liquid in the air



Human Hair (45 - 130 μm diameter)

Hair cross section ($\sim 100 \mu\text{m}$)



PM_4
(4 μm)

$\text{PM}_{2.5}$
(2.5 μm)

Potential Health Impacts linked to diesel:

Ozone, fine particles, toxic compounds from diesel engines can cause or exacerbate:

- Asthma;
- Chronic bronchitis;
- Chronic obstructive airway disease;
- Cardio-pulmonary morbidity and mortality;
- Cancer... “highly likely to cause cancer in humans”
- 40 known or suspected cancer causing agents in the exhaust mixture....

The Multiple Air Toxics Exposure Study II

- Monitored 30 toxic air pollutants at 24 sites
- Conducted a computer dispersion modeling study (included emissions inventory development)
- Estimated the risk of developing cancer over a lifetime of inhalation exposure

Reference: South Coast Air Quality Management District,
November, 1999.

The Multiple Air Toxics Exposure Study II

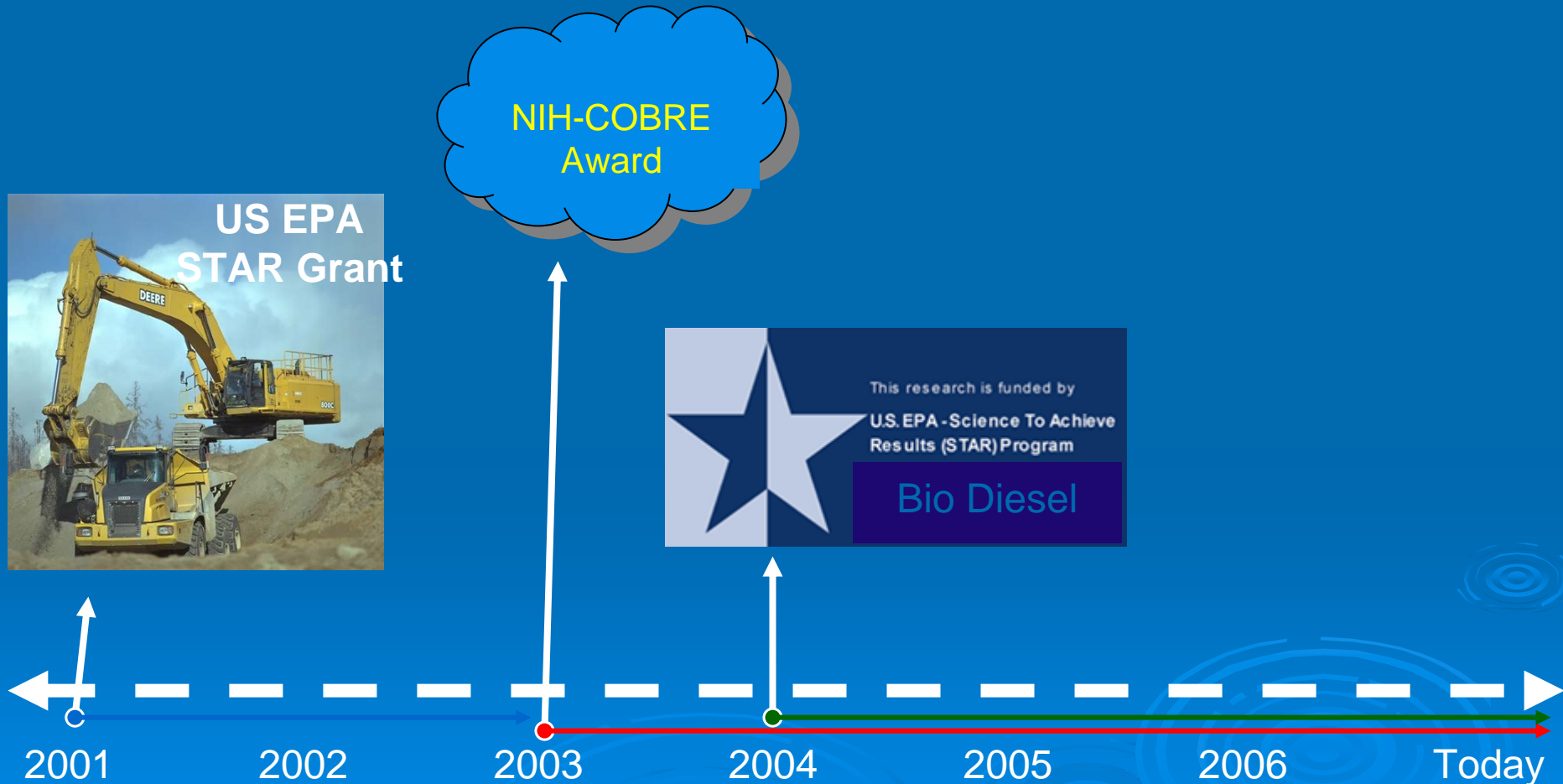
Findings:

- Diesel soot accounted for 71% of the cancer risk,
- 1,3 butadiene 8% of the risk,
- benzene 7%,
- carbonyls 3%, and
- others (primarily from stationary sources) 11%.

Led to AGGRESSIVE diesel (on-road and non-road) emissions control---state and local air quality control

Keene State College Safety Studies Department

Research Activities evaluating diesel and biodiesel emissions



KSC Exposure Assessment for Petroleum Diesel in Non-Road Sector

Goals for our work:

- To evaluate occupational exposures and environmental impact of nonroad diesel equipment activity
- To qualify (and to the degree possible quantify) health risks for exposed populations
- To consider the health-protectiveness of federal standards

Conclusions

Non-road heavy-duty diesel equipment activity substantially increased* fine particulate matter exposures.

*Average concentrations were 1-16X greater than normally recorded in each area.

Conclusions

Non-road heavy-duty diesel equipment activity increased* diesel particulate matter exposures.

*Other projects have concluded that, in an urban environment, diesel particulate “background” ranges between 0.4 – 1.5 $\mu\text{g}/\text{m}^3$. These data demonstrate that nonroad equipment activities will increase these concentrations by 1 - 6 X.

Conclusions

- Concentrations of several monitored gaseous pollutants are several hundred times greater than carcinogenic risk screening thresholds
- Concentrations of toxic metals vary across sites and in some cases exceed established allowable exposure concentrations.

Occupational and Environmental Health Standards

	EPA	OSHA	MSHA	Occupational v.s. Environmental
PM_{2.5}	0.035 mg/m ³	5 mg/m ³	N/A	+ 99.3 %
Diesel Soot (EC)	0.005 mg/m ³	N/A	0.16 mg/m ³	+ 96.9 %

Georgia



9,072,576
People

OSHA = 5 mg/m³

- 99.3 % LARGER than EPA
- 8 Hour concentration

EPA = 0.035 mg/m³


- 7/1000 the size of OSHA
- 24 Hour Concentration



1,317,000,000
People

Fuels and Air Quality

Motor vehicles in the Northeast:

- Emit 1/3 smog forming volatile organic compounds and oxides of nitrogen in the region (2/3 if include non-road engines)
 - Are the primary source of carbon monoxide
 - Emit 80-90% of four priority toxic compounds on a regional average
- 

Direct mobile source emissions:

Regional Average:

	<u>On-road</u>	<u>Non-road</u>
Acetaldehyde	30%	70%
Benzene	54%	46%
1,3-Butadiene	67%	33%
Formaldehyde	40%	60%
Particulate matter	82%	18%

KSC Inventory assessment—Non-road Engines

- Non-road motor vehicle sector is expected to replace the on-road sector as the largest source of air toxic emissions from the mobile sector by 2008.

(72-90%) of primary acetaldehyde and formaldehyde emissions in both rural and urban states in the Northeast.

- Non-road diesel engines are projected to contribute up to 70% of the total mobile source particulate emissions by 2010.

KSC Inventory assessment—Non-road Construction Equipment


Construction equipment in the Northeast emits 10% of all nitrogen oxides. Precursors to ozone and secondary fine particles.

Construction equipment in the Northeast emits 33% of all mobile source $PM_{2.5}$. This is particularly challenging in urban areas.

In the Northeast alone, approximately 48,000 - 200,000 employees are believed to be exposed daily to diesel exhaust concentrations from construction equipment activities.

What about Stationary Source Engines burning Petroleum Diesel?

We've looked at ski areas-
stationary generators supporting
snowmaking...

The background of the slide features several sets of concentric circles in a lighter shade of blue, resembling ripples in water. These circles are positioned in the lower half of the slide, with one set on the left, one in the center, and a larger one on the right.

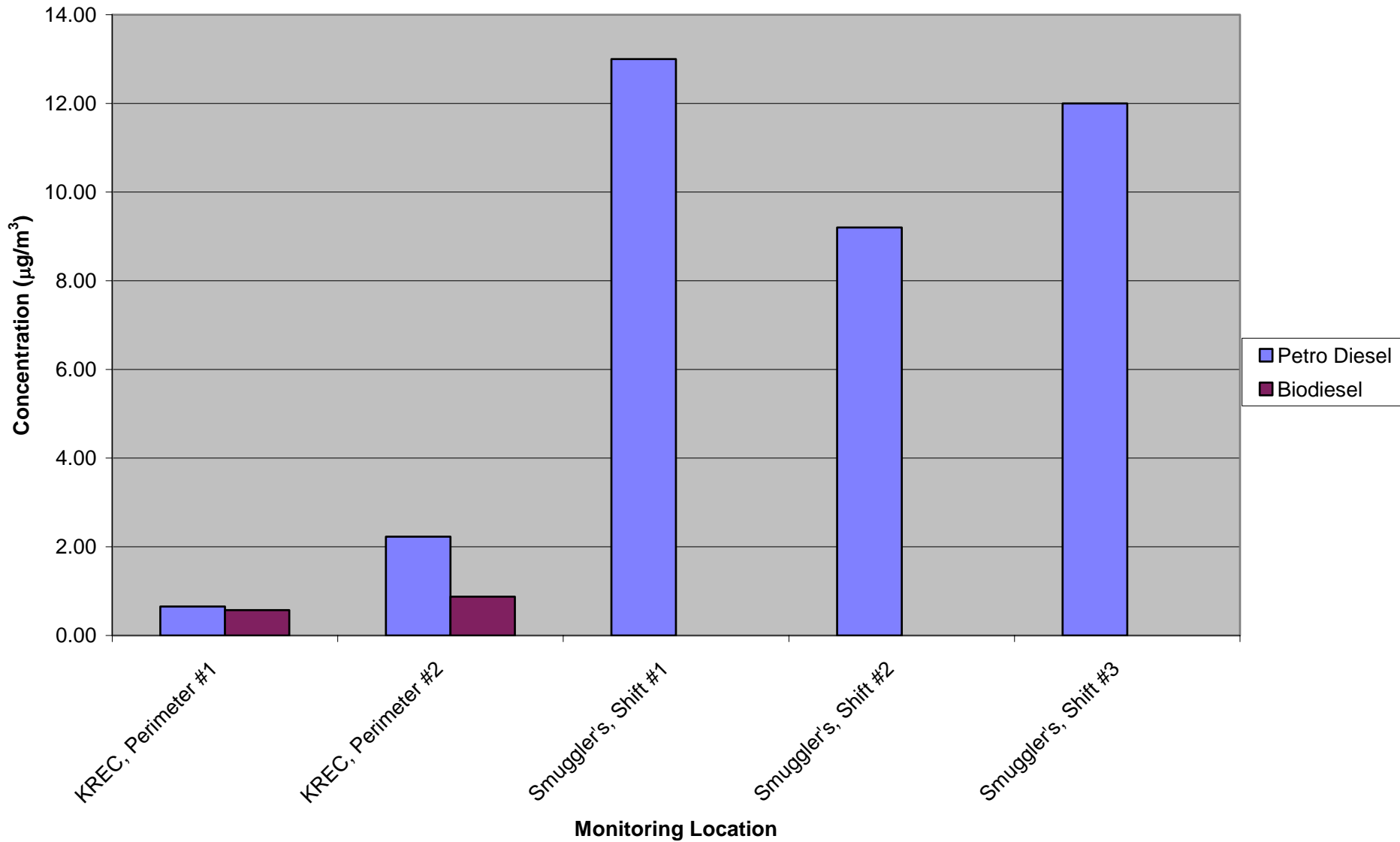
Measured *Average* Fine Particulate Matter Concentration

Location	8-hour Average Concentration ($\mu\text{g}/\text{m}^3$)
New York City 09/14-17, 2002	73 (highest measured)
Smuggler's Notch, Shift #1	400
Smuggler's Notch, Shift #2	220
Smuggler's Notch, Shift #3	110

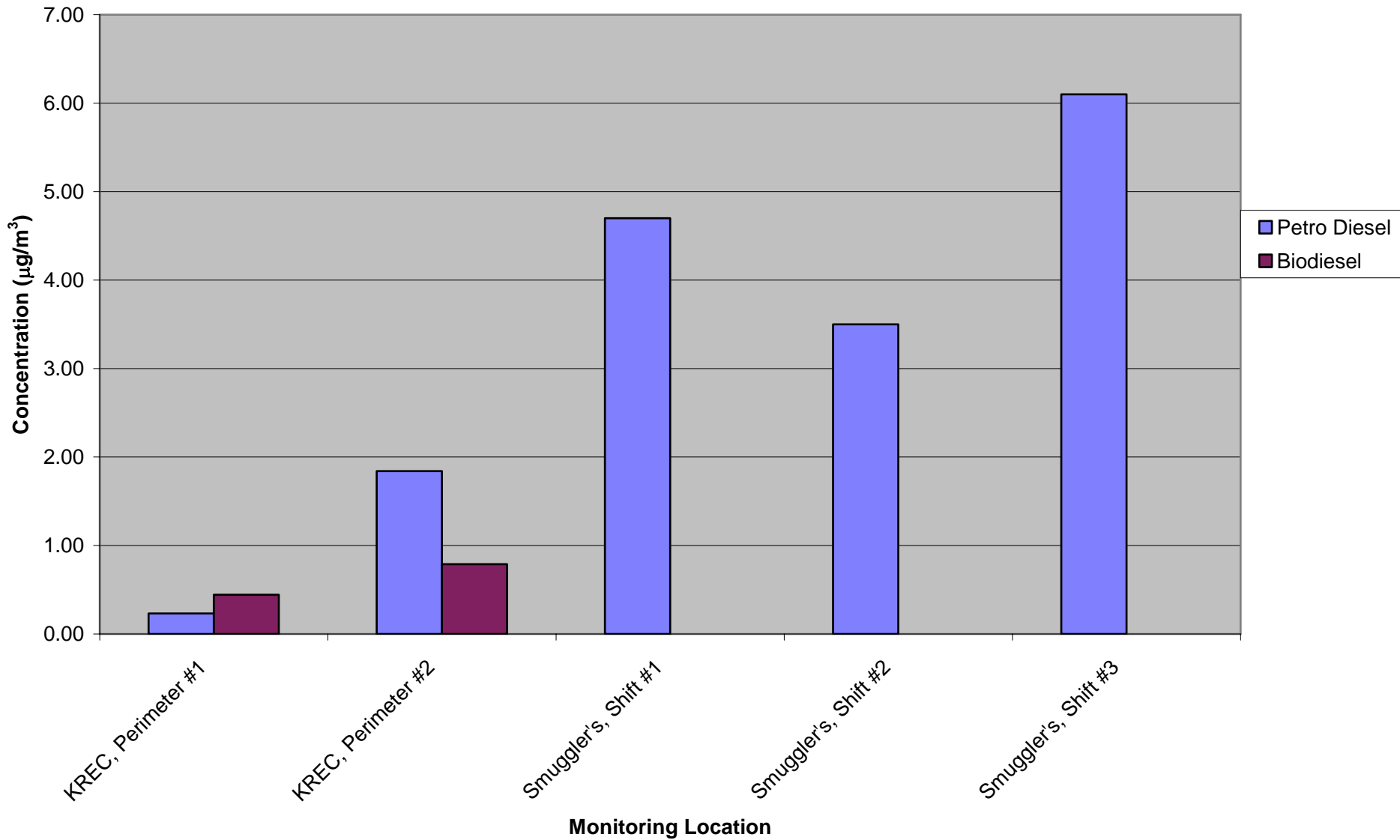
EPA requires a 24-hour fine particulate matter exposure of less than $35 \mu\text{g}/\text{m}^3$

Our Smuggler's Notch 24-hour average was $243 \mu\text{g}/\text{m}^3$

Measured Formaldehyde Concentration



Measured Acetaldehyde Concentration



Standards



➤ OSHA

- OSHA PEL - all 'respirable' particles not otherwise regulated, which is **5 mg/m³**

➤ EPA

- **NAAQS** - National Ambient Air Quality Standards
- Include annual and 24hr PM_{2.5} standards
- In 2006 the 24hr PM_{2.5} standard was changed from **65 µg/m³** to **35 µg/m³** (**0.035 mg/m³**)

Why not await the pending federal requirements?

Fuel and new engine standards for highway and non-road diesel engines on the way...



Highway Diesel Fuel

- **500 ppm:** Sulfur limit of 500 ppm = 0.05% (wt.) became effective in October 1993.
 - *Low sulfur* diesel fuel was introduced to facilitate sulfate particulate emission reductions required by USEPA1994 emission standards for heavy-duty highway engines.
- **15 ppm:** Diesel fuel of maximum sulfur level of 15 ppm will be available for highway use beginning in June 2006.
 - *Ultra low sulfur diesel (ULSD)*, was legislated by the EPA to enable catalyst-based emission control devices, such as diesel particulate filters and NOx adsorbers, necessary for meeting the 2007-2010 emission standards for heavy-duty engines.

Source: <http://www.dieselnet.com/standards/us/fuel.html>

Nonroad Diesel Fuels

- **500 ppm:** Sulfur limit of 500 ppm becomes effective in June 2007 for nonroad, locomotive and marine fuels.
- **15 ppm:** Sulfur limit of 15 ppm (ULSD) becomes effective in June 2010 for nonroad fuel, and in June 2012 for locomotive and marine fuels.

Why not await the pending federal requirements?

- Phase in for nonroad emission controls 2008 and 2014.
- New fuels and engine technologies likely not in the field for years - decades to come.
- Current challenges with ultra low sulfur diesel for on-road engines and engine technology delays (2007 standards) will be a problem...
- After market emissions controls, cleaner fuels, or other emission reduction efforts focused on the current fleet or stationary engines will mean exposure reductions and environmental improvement immediately.

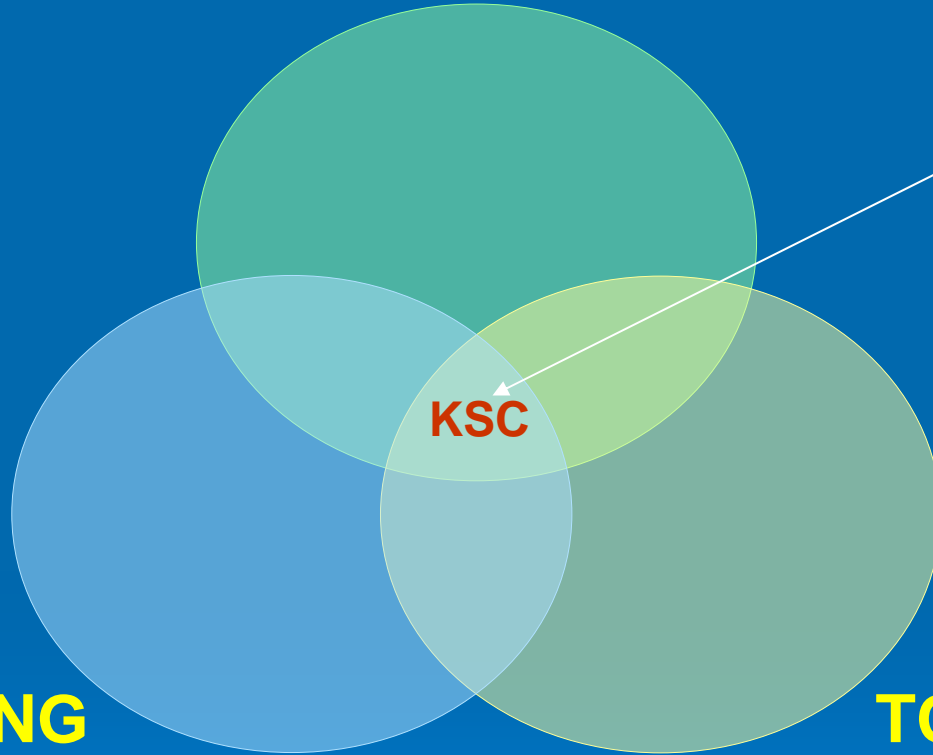
**DECISION-MAKING
& POLICY**

Does
biodiesel
help to
control
emissions?

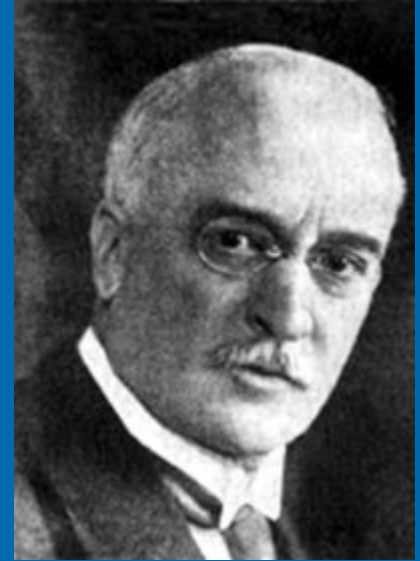
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ENGINEERING

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Rudolf C. K. Diesel



"the use of vegetable oils for engine fuels may seem insignificant today but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time."

- 1912 speech, Rudolf Diesel



Biodiesel Fuels

- The first national biodiesel specification in the USA has been the ASTM standard D 6751, “*Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels*”, adopted in 2002.
- The D 6751 standard covers biodiesel (B100) used as a blending component with petroleum diesel fuels.

Early dynamometer tests—a solution to petroleum diesel ills??

Pollutant	B100	B20
Hydrocarbons	-80-90%	-21%
CO	-40%	-11%
Particulate Matter	-30-50%	-10%
NOx	+12%	+2%
Sources:	www.biodiesel.org www.epa.gov	

If biodiesel is the
answer....

What's the question?



Political & economic arguments for biodiesel

- Need for renewable energy
- Decreases U.S. reliance on foreign oil
- Increases jobs in agricultural & manufacturing sector

What do people in Keene think?

- 50% of respondents supported biodiesel use in Keene because it is “good for the environment”.
- 37.5% supported biodiesel use to “reduce dependence on foreign oil”
- 100% think biodiesel is “healthier”...but 89% believe more research is needed to understand biodiesel’s “risks/benefits”
- Cost, while not a major issue with the Keene group, is also not a non-issue

Keene State College

- Using biodiesel since 2002
- Garbage truck, snow plows, dump trucks, lawn mowers, bobcats, front end loaders, & tractors
- Grounds staff reported less headaches, less nausea, less eye & respiratory irritation

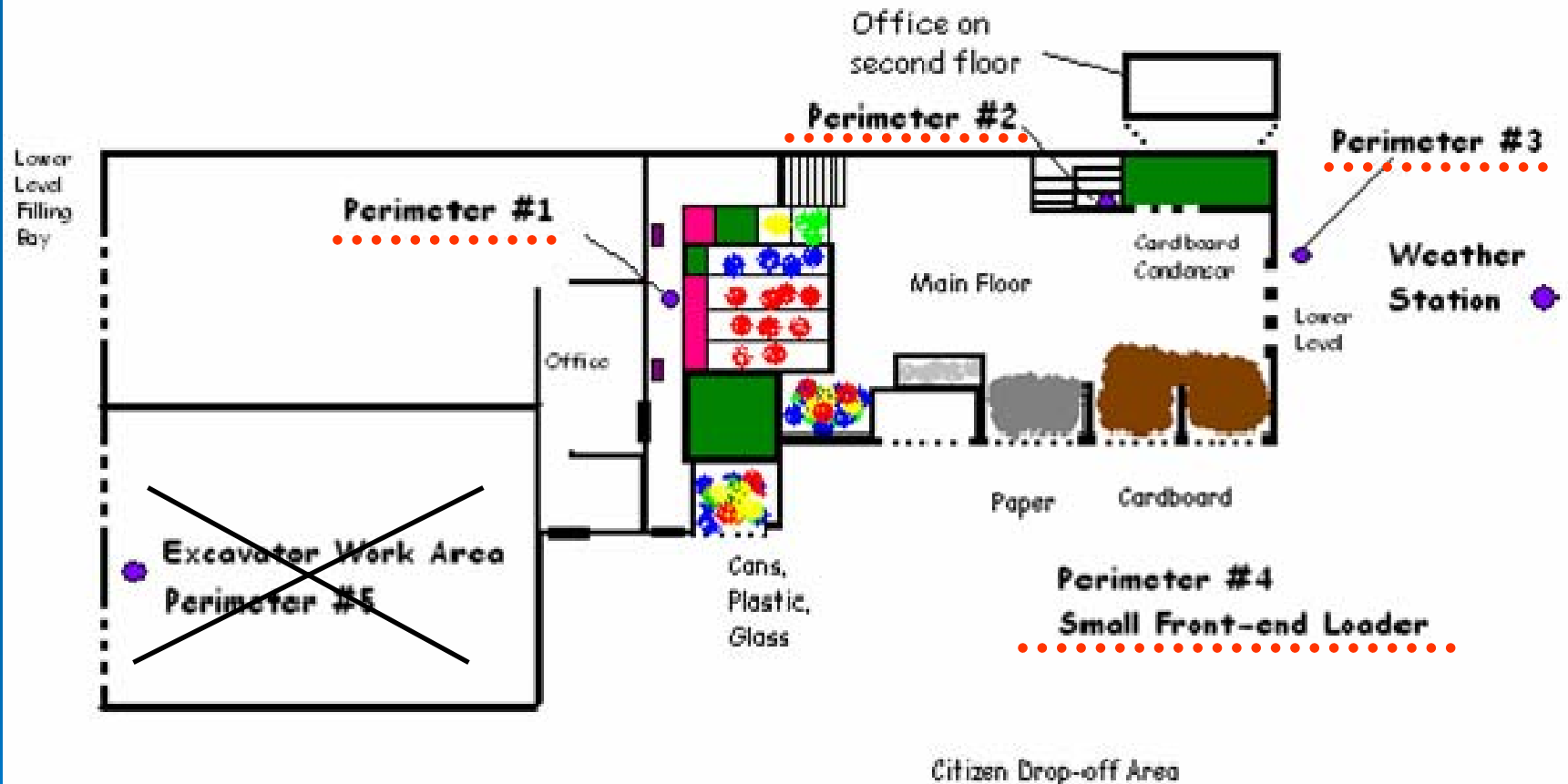


City of Keene

- Also began using in 2002
- Dedicated a 20,000 gallon UST
- Use in 150+ vehicle fleet
- Employees reported less headaches, less nausea, less eye & respiratory irritation
- This John Deere is from Recycling Center



Keene Recycling Center



MUNICIPAL FACILITY

Central Question for our research

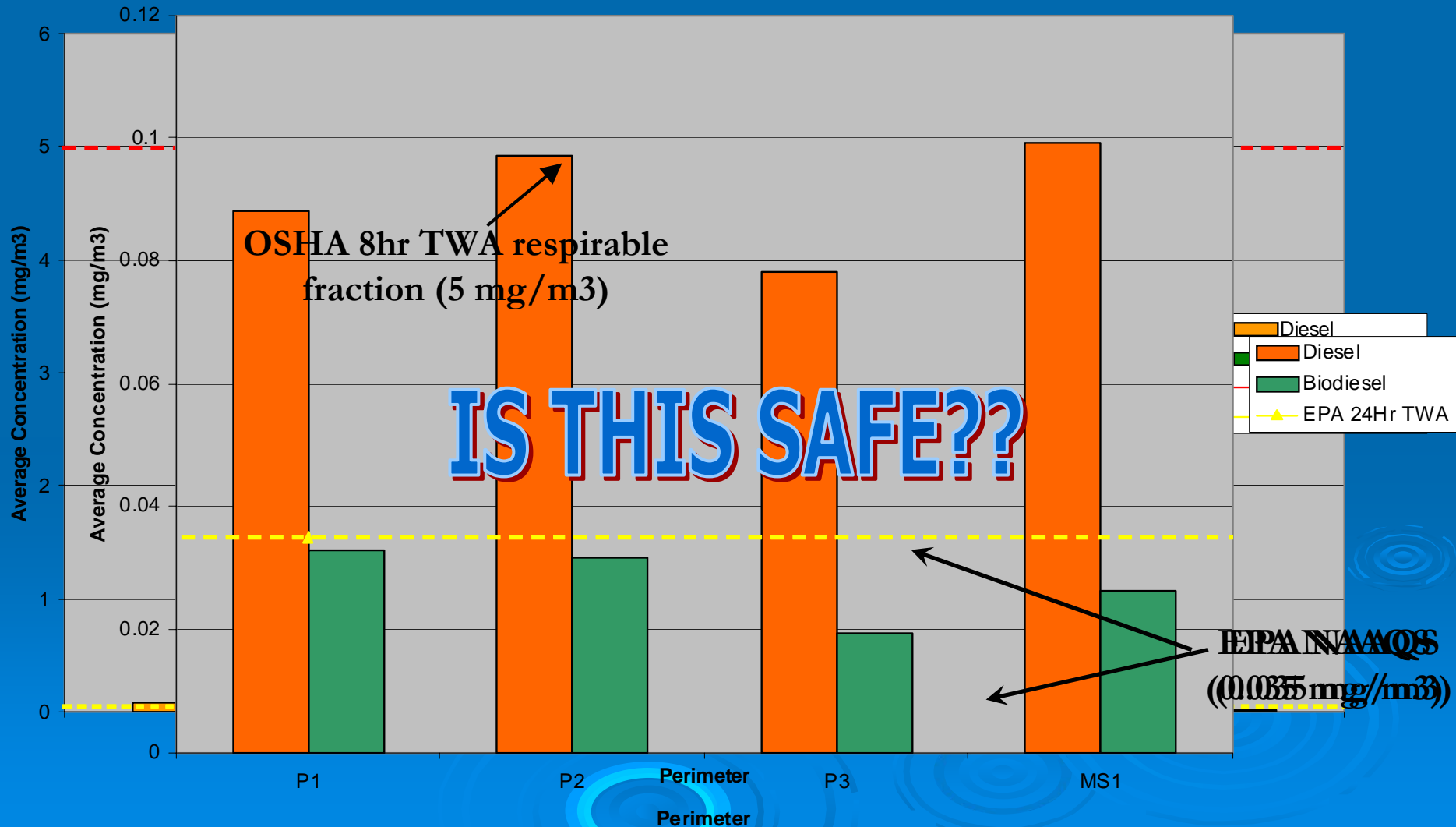
➤ Does B20 use result in lower emissions of:

- PM2.5;
- Elemental/Organic Carbon;
- Oxides of Nitrogen; and
- Toxic metals of interest?

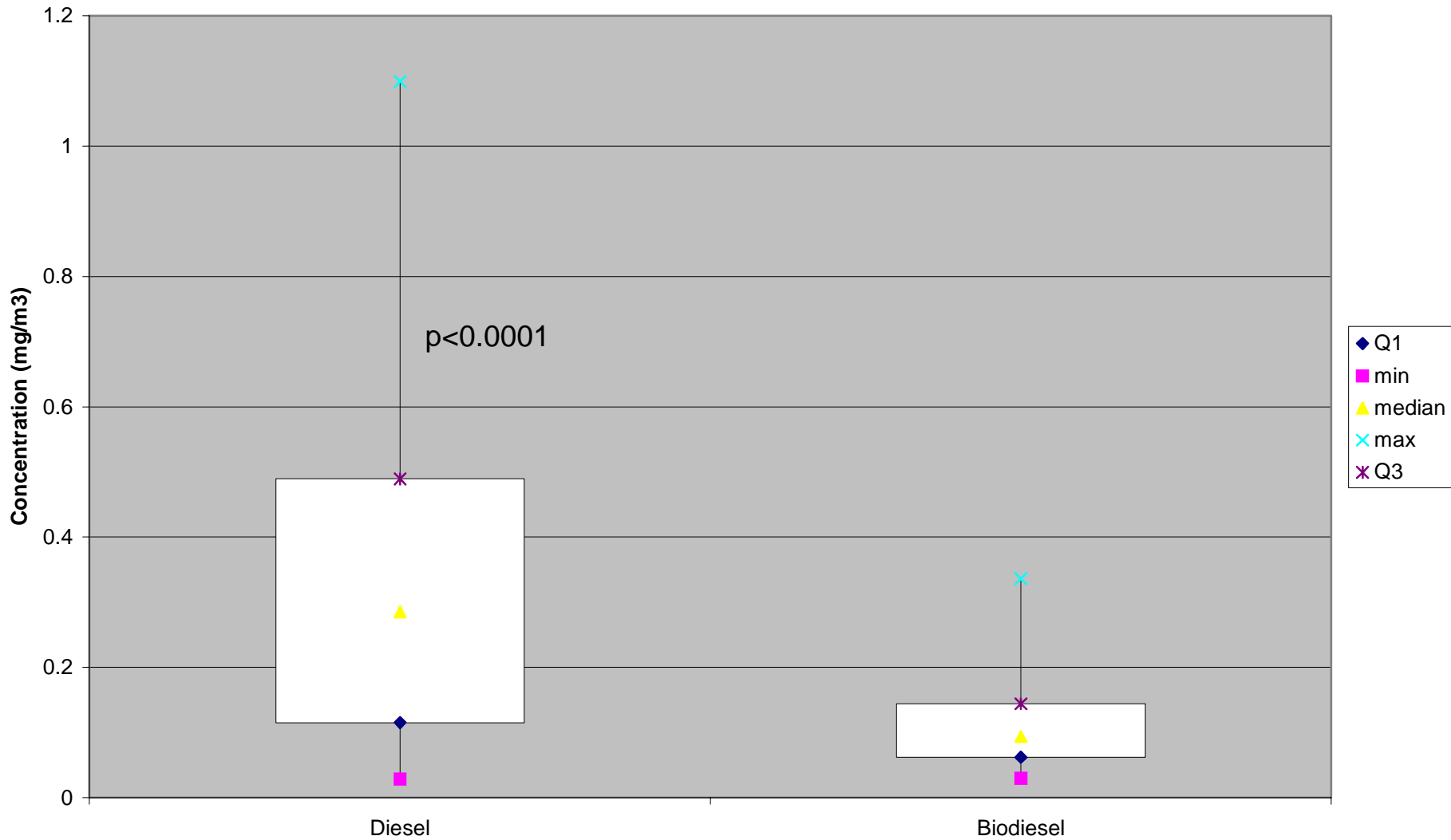
We employed state of the art occupational and environmental exposure monitoring methods

Some Preliminary Results

24 HR TWA Averages Using Ambient Air Data
24 HR TWA Averages Using Ambient Air Data

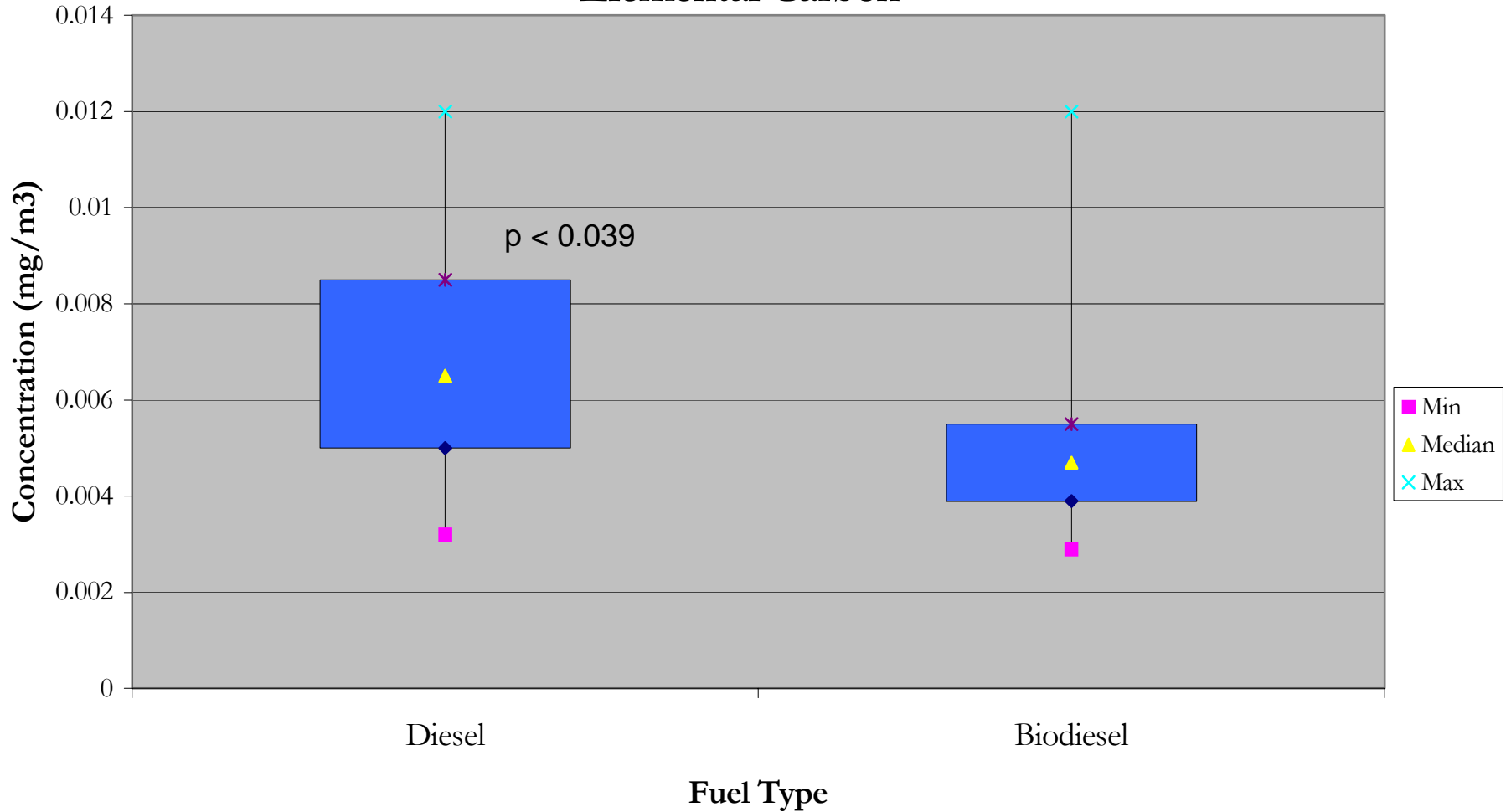


Total Daily Average Particulate Matter 2.5 Concentrations (P1, P2, P3, MS1) Diesel vs. Biodiesel



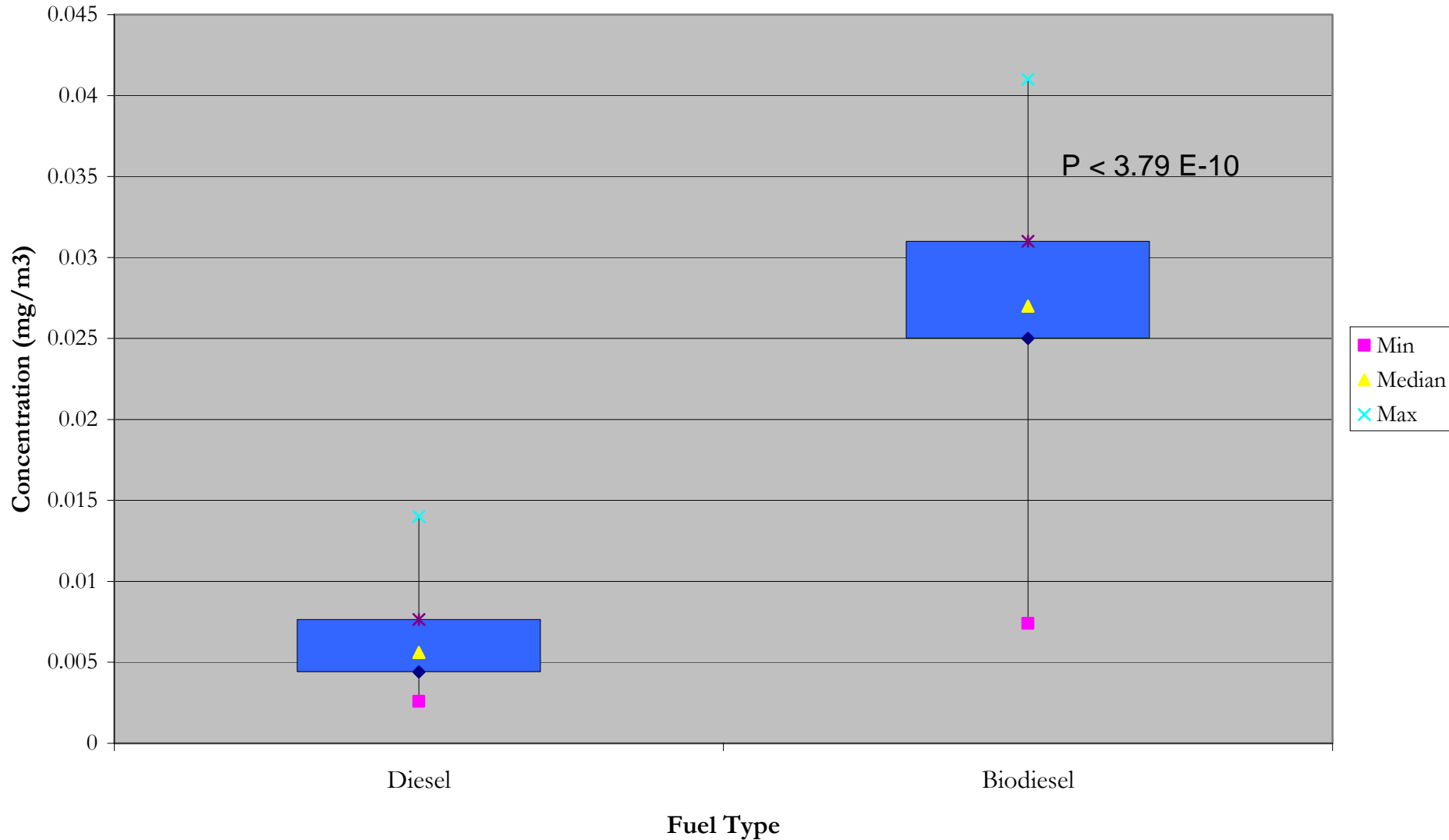
~ 66 % reduction in PM_{2.5} concentration with B20 blend

Diesel vs. Biodiesel Elemental Carbon



~ 29 % reduction in elemental carbon concentration with B20 blend

Diesel vs. Biodiesel Organic Carbon



~ 322 % increase in organic carbon concentration with B20 blend

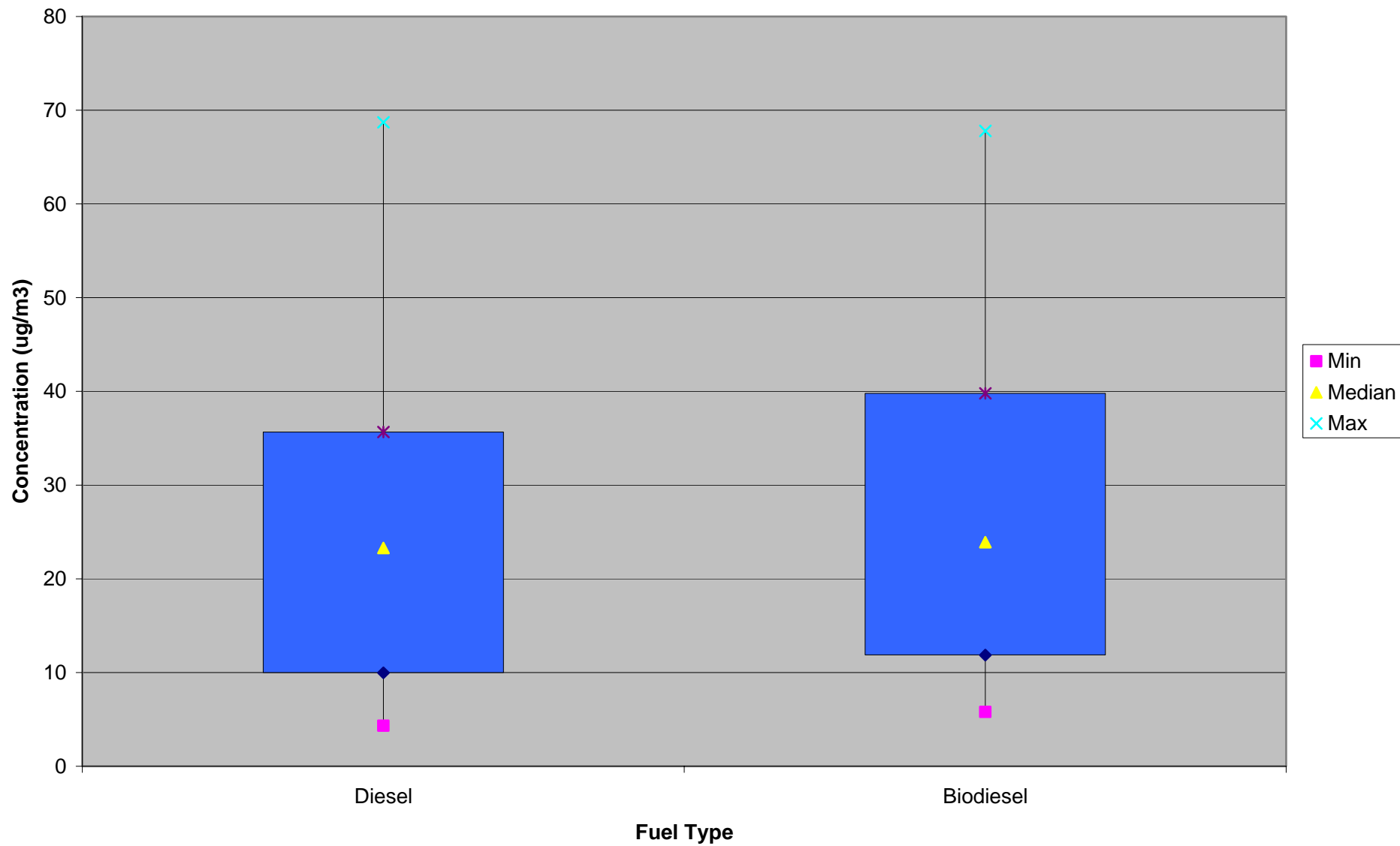
Nitrogen oxides - NO_x

- NO_x is an ozone precursor and Clean Air Act criteria pollutant
- NO_x leads to the formation of ground level ozone and smog

Sunlight + NO_x + VOC's + heat = smog

Many scientists are concerned about the impact of biodiesel on NO_x. An EPA study (2002) indicated NO_x should increase with increasing % biodiesel in the blend. Other scientists report the opposite – the “perfect storm” of policy controversy.

NO2 Statistics

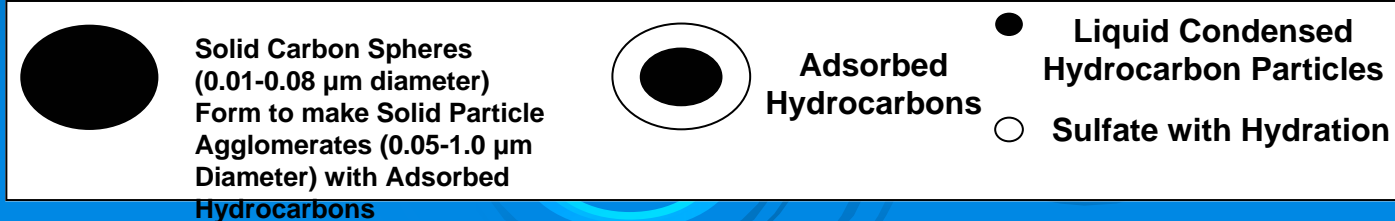
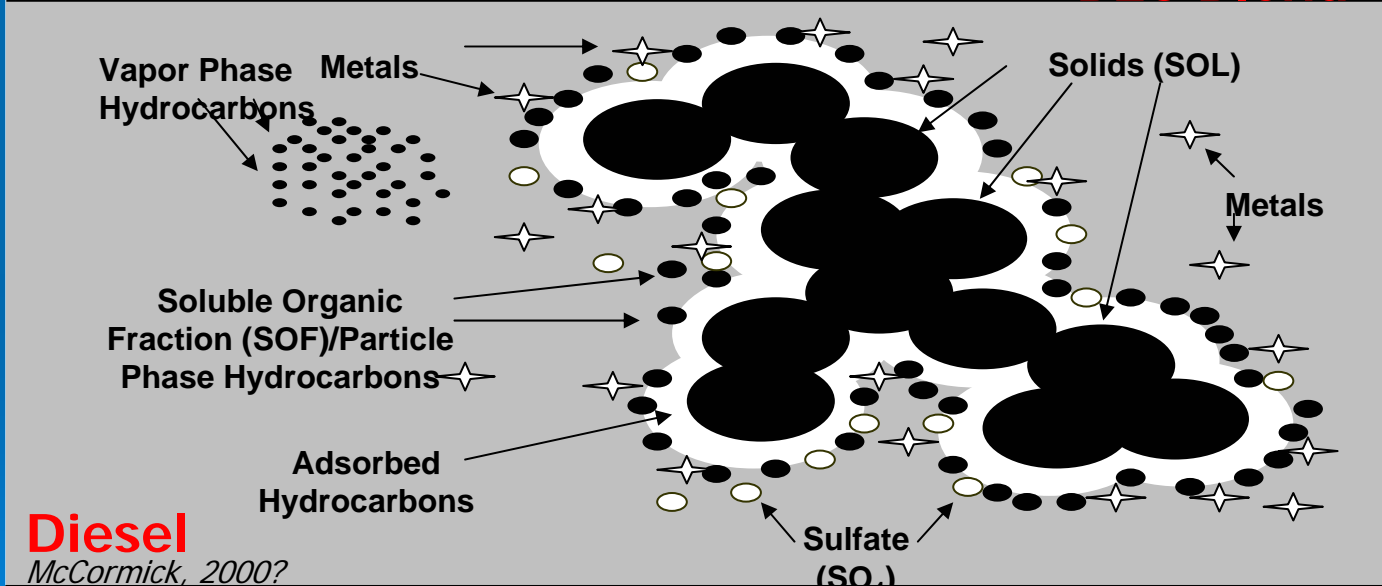
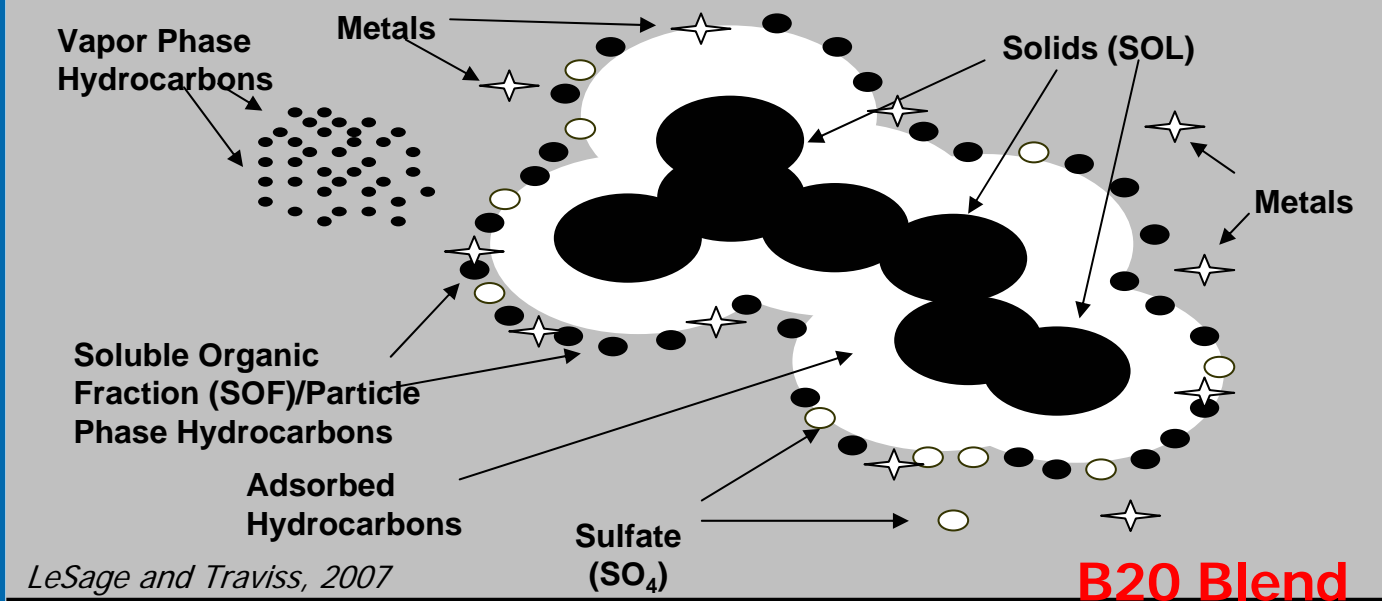


DRAFT Conclusions to Date

- B20 use appears to cause a statistically significant decrease in PM_{2.5} concentrations
- B20 use appears to cause a slight statistically significant decrease in elemental carbon concentrations
- B20 use appears to cause a statistically significant increase in Organic Carbon concentrations
- B20 use does not appear to cause a statistically significant change in NO₂ concentrations

Future Directions??

- If these reductions could be reproduced for stationary engines the emission reductions could be very substantial
 - 66% reduction in PM_{2.5}
 - 28% reduction in elemental carbon
 - NO_x change in stationary engines?
- The question of organic carbon increase must be further investigated
 - 322% increase attributable to what?



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